

WHAT IS CLAIMED IS:

1. A method of delivering combined positive and negative pressure assist ventilation to a patient, comprising:

5 applying a positive pressure to the patient's airways to inflate the patient's lungs;

 applying a negative pressure around the patient's ribcage and/or abdomen in order to reduce a load imposed by the ribcage and/or abdomen on the patient's lungs; and

10 synchronizing application of the positive and negative pressures.

2. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein synchronising application of the positive and negative pressures comprises:

15 simultaneously applying the positive pressure to the patient's airways and the negative pressure around the patient's ribcage and/or abdomen.

3. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, comprising:

20 adjusting levels of the positive and negative pressures to avoid application of excessive positive pressure to the patient's airways and thereby minimize hemodynamic adverse effects.

4. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a positive pressure to the patient's airways comprises:

 detecting neural inspiratory activation of the patient; and

 applying positive pressure to the patient's airways as a function of the detected neural inspiratory activation.

5. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 4, wherein synchronizing application of the positive and negative pressures comprises:

synchronizing triggering and termination of the application of the positive pressure to the patient's airways as a function of the detected neural inspiratory activation.

6. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a positive pressure to the patient's airways comprises:

determining a target level of neural inspiratory activation of the patient;
detecting a level of neural inspiratory activation of the patient;
comparing the detected level of neural inspiratory activation with the determined target level; and
controlling a level of positive pressure applied to the patient's airways as a function of the comparison.

7. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 6, wherein synchronizing application of the positive and negative pressures comprises:

synchronizing triggering and termination of the application of the positive pressure to the patient's airways in relation to the detected level of neural inspiratory activation.

8. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 6, wherein controlling the level of positive pressure applied to the patient's airways comprises:

increasing the level of positive pressure applied to the patient's airways when the comparison indicates that the detected level of neural inspiratory activation of the patient is higher than the determined target level.

9. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 6, wherein controlling the level of positive pressure applied to the patient's airways comprises:

5 decreasing the level of positive pressure applied to the patient's airways when the comparison indicates that the detected level of neural inspiratory activation of the patient is lower than the determined target level.

10 10. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 6, wherein controlling the level of positive pressure applied to the patient's airways comprises:

maintaining a present level of positive pressure applied to the patient's airways when the comparison indicates that the detected level of neural inspiratory activation of the patient is equal to the determined target level.

15 11. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a negative pressure around the patient's ribcage and/or abdomen comprises:

applying a constant negative pressure around the patient's ribcage and/or abdomen during patient's inspiration.

20 12. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a negative pressure around the patient's ribcage and/or abdomen comprises:

25 synchronizing triggering and termination of the application of negative pressure with triggering and termination of the application of positive pressure.

13. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a negative pressure around the patient's ribcage and/or abdomen comprises:

30 detecting neural inspiratory activation of the patient; and
applying the negative pressure around the patient's ribcage and/or abdomen as a function of the detected neural inspiratory activation.

14. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a negative pressure around the patient's ribcage and/or abdomen comprises:

5 determining a target level of an abdominal pressure swing of the patient;

 detecting a level of abdominal pressure swing of the patient;

 comparing the detected level of abdominal pressure swing with the determined target level; and

10 controlling a level of negative pressure applied around the patient's ribcage and/or abdomen as a function of the comparison.

15 15. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 14, wherein controlling the level of negative pressure applied around the patient's ribcage and/or abdomen comprises:

 increasing the level of negative pressure applied around the patient's ribcage and/or abdomen when the comparison indicates that the detected level of abdominal pressure swing of the patient is higher than the determined
20 target level.

25 16. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 14, wherein controlling the level of negative pressure applied around the patient's ribcage and/or abdomen comprises:

 decreasing the level of negative pressure applied around the patient's ribcage and/or abdomen when the comparison indicates that the detected level of abdominal pressure swing of the patient is lower than the determined
30 target level.

17. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 14, wherein controlling the level of

negative pressure applied around the patient's ribcage and/or abdomen comprises:

maintaining a present level of negative pressure applied around the patient's ribcage and/or abdomen when the comparison indicates that the
5 detected level of abdominal pressure swing of the patient is equal to the determined target level.

18. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, further comprising applying a constant Negative
10 End-Expiratory Pressure over the abdomen to adjust an end-expiratory lung-volume.

19. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 18, comprising applying the constant Negative End-
15 Expiratory Pressure over the abdomen in combination with inspiratory negative pressure assist ventilation.

20. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 18, comprising applying the constant Negative End-
20 Expiratory Pressure over the abdomen in proportional response to tonic inspiratory muscle activation occurring during expiration.

21. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 1, wherein applying a negative pressure
25 comprises obtaining an intrathoracic pressure estimate by measuring an airway pressure deflection during a patient's airway occlusion.

22. A method of delivering combined positive and negative pressure assist ventilation as defined in claim 21, wherein, in case of intrinsic PEEP,
30 obtaining an intrathoracic pressure estimate includes an extrapolation for the period between an onset of electrical activity of the patient's diaphragm activity and an onset of the patient's airway pressure deflection.

23. A system for delivering combined positive and negative pressure assist ventilation to a patient, comprising:

5 a positive pressure ventilator connected to the patient's airways for applying a positive pressure to the patient's airways to inflate the patient's lungs;

a negative pressure ventilator installed on the patient's ribcage and/or abdomen for applying a negative pressure around the patient's ribcage and/or abdomen in order to reduce a load imposed by the ribcage and/or abdomen on the patient's lungs; and

10 a controller connected to the positive and negative pressure ventilators for controlling operation of said positive and negative pressure ventilators.

15 24. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 23, wherein the controller synchronizes operation of the positive and negative pressure ventilators to apply the positive pressure to the patient's airways and the negative pressure around the patient's ribcage and/or abdomen simultaneously.

20 25. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 23, comprising a sensor of neural inspiratory activation of the patient, the controller being responsive to the neural inspiratory activation detected by the sensor to control the positive pressure ventilator.

26. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 23, comprising:

30 means for supplying a target level of neural inspiratory activation of the patient; and

a sensor of neural inspiratory activation of the patient;

wherein the controller comprises a comparator of the detected level of neural inspiratory activation with the determined target level to control the positive pressure ventilator in relation to this comparison.

5 27. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 23, wherein the controller controls the negative pressure ventilator to apply a constant negative pressure around the patient's ribcage and/or abdomen during patient's inspiration.

10 28. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 23, comprising:
a sensor of neural inspiratory activation of the patient;
wherein the controller is responsive to the neural inspiratory activation to control the negative pressure ventilator.

15 29. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 23, comprising:
means for supplying a target level of an abdominal pressure swing of the patient; and
20 a sensor of a level of abdominal pressure swing of the patient;
the controller comprising a comparator of the detected level of abdominal pressure swing with the determined target level to control the negative pressure ventilator as a function of the comparison.

25 30. A system for delivering combined positive and negative pressure assist ventilation to a patient, comprising:
first means for applying a positive pressure to the patient's airways to inflate the patient's lungs;
second means for applying a negative pressure around the patient's
30 ribcage and/or abdomen in order to reduce a load imposed by the ribcage and/or abdomen on the patient's lungs; and

means for synchronizing operation of the first and second pressure-applying means.

31. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the synchronizing means comprises:

means for simultaneously applying the positive pressure to the patient's airways and the negative pressure around the patient's ribcage and/or abdomen.

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32. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, comprising:

means for adjusting levels of the positive and negative pressures to avoid application of excessive positive pressure to the patient's airways and thereby minimize hemodynamic adverse effects.

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33. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the first means comprises:

means for detecting neural inspiratory activation of the patient; and

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means for applying positive pressure to the patient's airways as a function of the detected neural inspiratory activation.

34. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 33, wherein the synchronizing means comprises:

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means for synchronizing triggering and termination of the application of the positive pressure to the patient's airways as a function of the detected neural inspiratory activation.

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35. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the first means comprises:

means for determining a target level of neural inspiratory activation of the patient;

means for detecting a level of neural inspiratory activation of the patient;

5 means for comparing the detected level of neural inspiratory activation with the determined target level; and

means for controlling a level of positive pressure applied to the patient's airways as a function of the comparison.

10 36. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 35, wherein the controlling means comprises:

means for increasing the level of positive pressure applied to the patient's airways when the comparison indicates that the detected level of
15 neural inspiratory activation of the patient is higher than the determined target level.

37. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 35, wherein the controlling means
20 comprises:

means for decreasing the level of positive pressure applied to the patient's airways when the comparison indicates that the detected level of neural inspiratory activation of the patient is lower than the determined target level.

25 38. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 35, wherein the controlling means comprises:

means for maintaining a present level of positive pressure applied to
30 the patient's airways when the comparison indicates that the detected level of neural inspiratory activation of the patient is equal to the determined target level.

39. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the second means comprises:

- 5 means for applying a constant negative pressure around the patient's ribcage and/or abdomen during patient's inspiration.

40. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the synchronizing means
10 comprises:

 means for synchronizing triggering and termination of the application of negative pressure with triggering and termination of the application of positive pressure.

15 41. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the second means comprises:

- means for detecting neural inspiratory activation of the patient; and
 means for applying the negative pressure around the patient's ribcage
20 and/or abdomen as a function of the detected neural inspiratory activation.

42. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the second means comprises:

- 25 means for determining a target level of an abdominal pressure swing of the patient;
 means for detecting a level of abdominal pressure swing of the patient;
 means for comparing the detected level of abdominal pressure swing with the determined target level; and
30 means for controlling a level of negative pressure applied around the patient's ribcage and/or abdomen as a function of the comparison.

43. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 42, wherein the controlling means comprises:

5 means for increasing the level of negative pressure applied around the patient's ribcage and/or abdomen when the comparison indicates that the detected level of abdominal pressure swing of the patient is higher than the determined target level.

44. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 42, wherein the controlling means comprises:

10 means for decreasing the level of negative pressure applied around the patient's ribcage and/or abdomen when the comparison indicates that the detected level of abdominal pressure swing of the patient is lower than the
15 determined target level.

45. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 42, wherein the controlling means comprises:

20 means for maintaining a present level of negative pressure applied around the patient's ribcage and/or abdomen when the comparison indicates that the detected level of abdominal pressure swing of the patient is equal to the determined target level.

25 46. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, further comprising means for applying a constant Negative End-Expiratory Pressure over the abdomen to adjust an end-expiratory lung-volume.

30 47. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 46, wherein the constant Negative End-Expiratory Pressure applying means comprises means for applying the constant Negative

End-Expiratory Pressure over the abdomen in combination with inspiratory negative pressure assist ventilation.

5 48. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 46, wherein the constant Negative End-Expiratory Pressure applying means comprises means for applying the constant Negative End-Expiratory Pressure over the abdomen in proportional response to tonic inspiratory muscle activation occurring during expiration.

10 49. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 30, wherein the means for applying a negative pressure comprises means for obtaining an intrathoracic pressure estimate by measuring an airway pressure deflection during a patient's airway occlusion.

15 50. A system for delivering combined positive and negative pressure assist ventilation as defined in claim 49, wherein, in case of intrinsic PEEP, the intrathoracic pressure estimate obtaining means comprises means for conducting an extrapolation of the intrathoracic pressure estimate for the
20 period between an onset of electrical activity of the patient's diaphragm activity and an onset of the patient's airway pressure deflection.